526 Rec'd PCT/PTO 18 JUL 2001

°FORM PTO-1390 (REV 11-2000) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER 449122009400
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. § 371		U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/889518 Not yet assigned
INTERNATIONAL APPLICATION NO. PCT/DE00/00005	INTERNATIONAL FILING DATE 3 January 2000	PRIORITY DATE CLAIMED 19 January 1999

TITLE OF INVENTION

METHOD FOR OBTAINING INFORMATION REGARDING INTERFERENCE IN THE RECEIVER OF A MESSAGE TRANSMISSION SYSTEM

APPLICANT(S) FOR DO/EO/US

Paul BAIER *et al.*

OIPE JC13 JUL 18 2001 PATENT & TRADEMARK OFFICE

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ has been communicated by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application under PCT Article 19 (35 U.S.C. 371(c)(2)).
   - a. ☒ is attached hereto.
   - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   - a. ☒ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☐ have not been made and will not be made.
8. ☒ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information: 1. IPER; 2. Int'l Search Report; 3. Application Data Sheet; 4. Return receipt postcard.

CERTIFICATE OF HAND DELIVERY

I hereby certify that this correspondence is being hand filed with the United States Patent and Trademark Office in Washington, D.C. on July 18, 2001.

R. Lynn Boyden

dc-271784

JC18 Rec'd PCT/PTO 18 JUL 2001

U.S. APPLICATION NO. (if known, see 37 CFR 1.5) Not yet assigned 09/889518	INTERNATIONAL APPLICATION NO. PCT/DE00/00005	ATTORNEY'SDOCKET NUMBER: 449122009400

21. ☒ The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $1,000.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO $860.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $710.00

International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provision of PCT Article 33(1)-(4) $690.00

International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) $100.00

CALCULATIONS PTO USE ONLY

				CALCULATIONS	PTO USE ONLY
ENTER APPROPRIATE BASIC FEE AMOUNT =				$860.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$130.00	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	29 - 20 =	9	x $18.00	$162.00	
Independent claims	1 - 3 =	0	x $80.00	$0	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $270.00	$270.00	
TOTAL OF ABOVE CALCULATIONS =				$1,422	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by ½.				$0	
SUBTOTAL =				$1,422	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$0	
TOTAL NATIONAL FEE =				$1,422	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00 per property** +				$0	
TOTAL FEES ENCLOSED =				$1,422	
				Amount to be refunded:	$
				charged:	$

a. ☒ Please charge my **Deposit Account No. 03-1952** in the amount of $1,422.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

b. ☒ The Commissioner is hereby authorized to charge any additional fees that may be required, or credit any overpayment to **Deposit Account No. 03-1952**. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Kevin R. Spivak
Morrison & Foerster LLP
2000 Pennsylvania Avenue, N.W.
Washington, D.C. 20006-1888

Kevin R. Spivak

SIGNATURE

Kevin R. Spivak
Registration No. 43,148

dc-271784

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09/889518

#3

PATENT
Docket No. 449122009400

CERTIFICATE OF HAND DELIVERY

I hereby certify that this correspondence is being hand filed with the United States Patent and Trademark Office in Washington, D.C. on August 27, 2001.

LaVerne Whetstone

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the application of:

Paul BAIER et al.

Serial No.: 09/889,518

Filing Date: July 18, 2001

For: METHOD FOR OBTAINING INFORMATION ABOUT INTERFERENCE IN THE RECEIVER OF A MESSAGE TRANSMISSION SYSTEM

Examiner: Not yet Assigned

Group Art Unit: Not yet Assigned

PRELIMINARY AMENDMENT

Commissioner for Patents
Washington, D.C. 20231

Sir:

Prior to the examination on the merits, please amend this application as follows:

In the Specification:

Page 1 before the first paragraph, has been amended to include the following insert:

CLAIM FOR PRIORITY

This application claims priority to International Application No. PCT/DE00/00005 which was published in the German language on January 3, 2000.

Page 1 before the first paragraph, please delete the following:

~~Description~~

Page 1, between lines 4 and 5 has been amended to include the following heading:

TECHNICAL FIELD OF THE INVENTION

Paragraph beginning on line 6 of page 1 has been amended as follows:

The invention relates to a method and a device for wireless data transmission, and in particular, to wireless data transmission where information about interference in a message transmission system is obtained in the receiver.

Page 1, between lines 10 and 11 has been amended to include the following heading:

BACKGROUND OF THE INVENTION

Paragraph beginning on line 11 of page 1 has been amended as follows:

In message or data transmission, it is desirable to obtain as uncorrupted a transmission of the user signals as possible, to suppress interference which exists at the same time and in the same frequency band in addition to the wanted signal, and thermal noise, as well as possible in the receivers. To be able to selectively take measures against interference, it is required to know as much as possible about the characteristics of the interference. Apart from the intensity of the

interference, such characteristics are, for example, its spectrum, its correlation properties and the directions of incidence of the interfering signals at the receiver.

Paragraph beginning on line 24 of page 1 has been amended as follows:

In many cases such as, for example, in permanently installed radio transmission links, potential interfering influences by other permanently installed transmitters, which do not emit any user signals from the point of view of the transmission link under consideration, are known. According to the prior art, such interfering influences can be suppressed by simple measures such as directional transmission and reception, a procedure normally used in microwave radio. In many cases, especially in the multi-subscriber systems of mobile communication, such information on the properties of the interference is not known. Accordingly, countermeasures adapted to the interference cannot be easily taken. Assuming interference-limited multi-subscriber systems in which, therefore, the interference is essentially caused by other users of one's own system, the time correlation of the interfering signals is equal to the time correlation of the wanted signals and is thus known as long as interfering signals which are incident from different directions are uncorrelated. Knowledge of the time correlation of the interfering signals can be utilized in the receiver for improving the transmission quality by decorrelating the interference.

Paragraph beginning on line 9 of page 2 has been amended as follows:

TD-CDMA as disclosed in A. Klein, P.W. Baier: Linear unibiased data estimation in mobile radio systems applying CDMA. IEEE Journal on Selected Areas in Communications, Vol. 11, 1993, p. 1058 to 1066, as an example for third-generation mobile radio systems, uses the hybrid FDMA/TDMA/CDMA (frequency/time/code division multiple access) method. The time correlation of the interfering signals can be taken into consideration in the data detection. An example in which no information about the correlation properties of the interference are utilized is the WCDMA (wideband CDMA) disclosed in F. Adachi, K. Ohno, A. Higashi, T. Dohi, Y.

Okumura: Coherent multicode DS-CDMA mobile radio access DS-CDMA mobile radio system, IEICE Transactions on Communications, Vol. E79-B, No. 9, 1996, p. 1316 to 1324 and F. Adachi, M. Sawahashi: Wideband multi-rate DS-CDMA for next generation mobile communications systems. Proc. IEEE Wireless Communications Conference (WCC'97), Boulder, 1997, p. 57 to 62, air interface concept which is also proposed for third-generation mobile radio systems and which is based on the hybrid FDMA/CDMA multiple access method.

Paragraph beginning on line 20 of page 2 has been amended as follows:

The disadvantageous factor in the transmission methods corresponding to the prior art, is that they do not obtain information on the received interference (or only to a very limited extent). Hence, they do not use such information to a desirable degree for improving the transmission quality. For example, no directional information at all is obtained with respect to the interference. If multiple-antenna receivers are used, directional patterns could be generated. For example, when using array antennas, which selectively have less gain for those directions from which strong interfering signals arrive at the receiver, the ratio between useful power and interference power at the receiver end is maximized. However, this would require knowledge of the directions of interference which cannot be obtained in the systems according to the prior art.

Paragraph beginning on line 1 of page 3 has been amended as follows:

The system described above of the time correlations of the interference, for example in the case of TD-CDMA, are not about obtaining information about the interference. Rather, using knowledge about the interference is questionable, especially in mobile communication, since the instantaneous characteristics of the interference can greatly deviate from those assumed due to the permanent changing in time of the spatial constellation of the mobile stations which, as a rule, is not predictable.

Paragraph beginning on line 12 of page 3 has been amended as follows:

The prerequisite of uncorrelated interference signals arriving at the receiver from different directions, which has been addressed above, is also not generally met. If the signal of an interference source propagates toward the receiver along a number of paths with different delay, and/or if the interfering signals coming from one interference source have different directions of incidence at the location of the receiver, the aggregate interference signal produced by superposition of the interference signals at the receiving location have different time correlations than the individual interference signals. Thus, they also have different time correlations from those of the user signal which have been assumed.

Page 3, between lines 25 and 26 has been amended to include the following heading:

<u>SUMMARY OF THE INVENTION</u>

In one embodiment of the invention, there is a method for the wireless data transmission using at least one transmitter and at least one receiver, the receiver having one or more receiving antenna. The method includes, for example, utilizing information on received interference signals to improve the quality of transmission of the data transmission, obtaining quantitative information about received user signals from the received signals of one of the antennas by using a first signal processing algorithm, and obtaining quantitative information about the received interference signals from the received signals of one of the antennas and the quantitative information obtained about the received user signals by using a second signal processing algorithm wherein the quantitative information about the received interference signals is used to generate a directional pattern at the transmitter.

In one aspect of the invention, the first signal processing algorithm provides an estimate of the transmitted user data.

In another aspect of the invention, the first signal processing algorithm provides an estimate of the characteristics of the radio channels operating between the transmitters and the receiver.

In still another aspect of the invention, the second signal processing algorithm includes algorithms to reconstruct the user signals received from the receiving antennas by the quantitative information obtained about the signals.

In yet another aspect of the invention, the second signal processing algorithm includes a weighted or unweighted subtraction of the reconstructed received user signals from the total received signals.

In another aspect of the invention, the second signal processing algorithm includes a forming of the spatial covariance matrix of the received interference signals.

In yet another aspect of the invention, the second signal processing algorithm includes a forming of the temporal covariance functions of the received interference signals at each of the antennas.

In still another aspect of the invention, the second signal processing algorithm includes a forming of the total covariance functions of the received interference signals.

In another aspect of the invention, the second signal processing algorithm includes an estimating of the spatial, temporal and/or total covariance functions by finite temporal averaging over the received interference signals.

In still another aspect of the invention, the second signal processing algorithm includes an estimating of the directions of incidence of the interference.

In yet another aspect of the invention, the second signal processing algorithm includes an estimating of the power and/or the spectral shape of the interference.

In another aspect of the invention, the first signal processing algorithm includes a forming of the spatial covariance matrix of the received user signals.

In yet another aspect of the invention, the first signal processing algorithm is based on the principle of a single user detection in the case of data transmission.

In another aspect of the invention, the first signal processing algorithm is based on a principle of multi-user detection in the case of data transmission.

In still another aspect of the invention, the first signal processing algorithm is based on a principle of a rake receiver in the case of data transmission.

In yet another aspect of the invention, the first signal processing algorithm includes forward error correction decoding at the receiver end during data transmission.

In still another aspect of the invention, the first signal processing algorithm is based on a principle of the zero-forcing algorithm.

In yet another aspect of the invention, the first signal processing algorithm is based on a principle of maximum-likelihood estimation or minimum mean square error estimation.

In one embodiment of the invention, there is a system for wireless data transmission. The system includes, for example, a receiver having one or more receiving antennas utilizing information on received interference signals to improve the quality of transmission of the data transmission, wherein quantitative information is obtained about received user signals from the received signals of one of the antennas by using a first signal processing algorithm, and the quantitative information about the received interference signals is obtained from the received signals of one of the antennas and the quantitative information obtained about the received user signals by using a second signal processing algorithm wherein the quantitative information about the received interference signals is used for generating a directional pattern at the transmitter; and a transmitter to generate a directional pattern based on the quantitative information about the received interference signals.

Page 3, between line 25 and line 26 has been amended to include the following:

<u>BRIEF DESCRIPTION OF DRAWINGS</u>

Figure 1 illustrates an exemplary receiving system in the present invention.

<u>DETAILED DESCRIPTION OF THE INVENTION</u>

Paragraph beginning on line 26 or page 3 has been amended as follows:

In one method of the invention, Ka receiving antennas are assumed. In this method, information on the user signal is first obtained from the received signals of the antennas. From the total received signals which contain both the user signal(s) and the interference signal(s), and the information, previously obtained about the user signal(s), information about the interference signal(s) can then be obtained.

Paragraph beginning on line 1 of page 4 has been amended as follows:

In one aspect of the invention, the information about the interference signals is obtained, for example, by an approximate reconstruction of the received user signals and by subsequent subtraction of the reconstructed user signals from the total of the received signals. This embodiment thus provides an estimate of the time functions $\underline{\hat{n}}^{(ka)}(t), ka = 1..Ka$ of the interference at the Ka receiving antennas.

Paragraph beginning on line 8 of page 4 has been amended as follows:

In another aspect of the invention, the estimates $\underline{\hat{n}}^{(ka)}(t)$ determined as above, the estimates

$$\underline{\hat{R}}_n^{(l.m)}(\tau) = E\{\underline{\hat{n}}^{(l)}(t) \cdot (t+\tau)\} \qquad l,m = 1..Ka \qquad (1)$$

of the temporal covariance functions of the interference signals effective at the antennas can be obtained. In addition, the normalized spatial covariance matrix

$$\underline{\hat{R}}_s = \frac{1}{\sigma^2}\begin{pmatrix} E\{\underline{\hat{n}}^{(1)}(t) \cdot \underline{\hat{n}}^{(1)} * (t)\} & E\{\underline{\hat{n}}^{(1)}(t) \cdot \underline{\hat{n}}^{(Ka)} * (t)\} \\ E\{\underline{\hat{n}}^{(2)}(t) \cdot \underline{\hat{n}}^{(1)} * (t)\} & E\{\underline{\hat{n}}^{(2)}(t) \cdot \underline{\hat{n}}^{(Ka)} * (t)\} \\ & \\ E\{\underline{\hat{n}}^{(Ka)}(t) \cdot \underline{\hat{n}}^{(1)} * (t)\} & E\{\underline{\hat{n}}^{(Ka)}(t) \cdot \underline{\hat{n}}^{(Ka)} * (t)\} \end{pmatrix}$$

(2)

of dimension Ka x Ka can be determined for the Ka receiving antennas, taking into consideration the interference power σ^2, which can also be determined from the estimated interference signals. In the case of both the data transmission and digital signal processing at the receiving end, discrete-time samples are available as signals which can be subdivided into finite blocks due to their burst structure. If the subscriber signals are detected burst by burst, it is sufficient to determine information about the interference burst by burst. Accordingly, the interference signals at the individual antennas,

estimated in accordance with the embodiments of the method according to one aspect of the invetion, can be represented as vectors

$$\underline{\hat{n}}^{(ka)} = \left(\underline{\hat{n}}_1, \underline{\hat{n}}_2 \ldots \underline{\hat{n}}_{WB}\right)^T, ka = 1..Ka \qquad (3)$$

where $\underline{\hat{n}}_i$, i=1..WB, are the WB samples of the interference signal over one burst, since these interference signals are time-discrete and limited in time. The embodiment of the method according to one aspect thus leads to finite, discrete-time covariance functions.

Paragraph beginning on line 9 of page 5 has been amended as follows:

Instead of forming the expected value when determining the covariance functions, which requires infinite averaging over the estimated samples of the interference, the temporal averaging is preferably finite in real systems. It is performed over a previously defined number Z of bursts. In the case of a mobile radio system, Z depends on the rate of change of the constellation of mobile stations. If the constellation of mobile stations changes greatly from burst to burst, Z must be selected to be equal to one. If not, Z can be greater than 1. If the Z vectors according to (3) at the Ka antennas according to

$$\hat{\underline{N}}_t^{(ka)} = \left(\hat{\underline{n}}_1^{Ka}, \hat{\underline{n}}_2^{Ka} \ldots \hat{\underline{n}}_Z^{Ka}\right)^T, ka = 1..Ka \qquad (4)$$

are ordered into in each case WB x Z matrices, estimates

$$\hat{\underline{R}}_n^{(l,m)} = \frac{1}{Z} \cdot \hat{\underline{N}}_t^{(l)} \cdot \hat{\underline{N}}_t^{(m)*T}, \qquad l, m = 1..Ka \qquad (5)$$

of the temporal covariance matrices can be formed in derivation of (1). The following then holds for the estimate of the total covariance matrices:

Paragraph beginning on line 34 of page 6 has been amended as follows:

An important advantage, which can be achieved with the method according to the invention, lies in

that, instead of possibly faulty information about the interference to be expected, the information about the interference is obtained from the actual received signal and is thus continuously updated. A further advantage lies in the possibility of obtaining information both on the spatial correlation characteristics of the interference and on the temporal correlation characteristics of the interference.

Paragraph beginning on line 5 of page 7 has been amended as follows:

This information can be used either directly to suppress interference when estimating the user signals from the received signals. Alternatively, information about the directions of incidence of the interference at the receiver can be obtained from the information about the spatial correlation characteristics of the interference, depending on the signal processing algorithm. In the case of multi-antenna receivers, the information about the directions of incidence of the interference at the receiver or, respectively, about the spatial correlation characteristics of the interference can be used for generating directional patterns. The patterns,

of which selectively have less gain in those directions from which strong interference signals arrive at the receiver, cause the ratio between useful power and interference power at the receiver end to be maximized.

Paragraph beginning on line 5 of page 7 has been amended as follows:

The previous considerations relate to the receiver end. In duplex systems, each receiver is paired with a transmitter. If multi-antenna systems are used for receiving and transmitting, the information about the received interference (obtained in accordance with the method explained above) can be used for advantageously driving the antennas in the transmitting case. The basic idea of this is that sending one's own signals into the directions from which strong interference signals are incident tends to produce strong interference in other receivers. When a number of antennas is used, therefore, the knowledge of the main directions of interference at the receiver end can be generally used, independently of the transmission system considered, to radiate as little power of the transmitted signal as possible in the directions of the main interference source and thus to reduce interference seen throughout the system.

Paragraph beginning on line 11 of page 8 has been amended as follows:

The transmitted bursts include two data blocks and a midamble arranged between them which provides for the channel estimate at the receiver end. In the text which follows, the first data block of a burst will be considered in the description of the data detection. A corresponding observation would apply to the second data block. According to R. Schmalenberger, J.J. Blanz: Multi antenna C/I balancing in the downlink of digital cellular mobile radio systems. Proc. IEEE Vehicular Technology Conference (VTC'97), Phoenix, 1997, p. 607 to 611, a system matrix A can be set up which includes both the K * Ka channel impulse responses of the K subscribers to the Ka receiving antennas and the type of signal generation at the transmitter end. Together with the total data vector d, which includes the data blocks of the K subscribers, and a total interference vector n, the total received-signal vector e

$$e = Ad + n \tag{12}$$

is obtained. e includes samples of the received signals at all Ka antennas which are based on the first data block of a transmitted burst. Firstly, a channel estimator 1 forms a channel estimate and a common detector 2 performs joint detection of the subscriber signals R. Schmalenberger, J.J. Blanz: Multi antenna C/I balancing in the downlink of digital cellular mobile radio systems. Proc. IEEE Vehicular Technology Conference (VTC'97), Phoenix, 1997, p. 607 to 611, by the generally disturbed received signals e. In TD-CDMA systems, algorithms which can include the knowledge of the entire covariance matrix according to (8) are used for the joint data estimate of subscribers.

Paragraph beginning on line 1 of page 9 has been amended as follows:

One example of such algorithms is the zero-forcing algorithm. In one- or multi-antenna receivers in systems according to the prior art, it is assumed that the temporal covariance matrix R_t can be determined directly from the spectral shape of the transmitted signals. In the text which follows, this covariance matrix is designated by R_t. This matrix R_t is taken into consideration in the data detection, even though the actual temporal correlations of the interference signals at the receiving site may deviate from the assumed temporal correlations due to multi-path propagation of the interference from an interference source.

Paragraph beginning on line 14 of page 9 has been amended as follows:

In the case of multi-antenna receivers in systems according to the prior art, the spatial correlations of the interference are not taken into consideration in the detection of the data and/or in the channel estimate, i.e. the covariance matrix R_s is replaced by the Ka x Ka unity matrix $I^{(Ka)}$. Thus, there is no optimum data detection in the sense of the zero-forcing algorithm in systems according to the prior art. The method according to the invention can be used for

improving the data estimate and the channel estimate by prior estimating of the covariance matrix R_n of the interference due to the estimating of the received interference at each antenna, as shown in figure 1.

Paragraph beginning on line 14 of page 9 has been amended as follows:

To estimate the interference, a conventional data detection is first performed for a number of received bursts, using the matrix

$$\underline{R}_n = I^{(Ka)} \otimes \underline{\tilde{R}}_t \qquad (13)$$

for the covariance matrix R_n according to (8), using the matrix $\underline{\tilde{R}}_t$. This provides an estimate

$$\hat{\underline{d}} = \left(\hat{\underline{A}}^{*T} \underline{R}_n^{-1} \hat{\underline{A}} \right)^{-1} \hat{\underline{A}}^{*T} \underline{R}_n^{-1} \underline{e} \qquad (14)$$

of the transmitted data which can be used for the approximate reconstruction of the received signal based on the user signals

$$\hat{\underline{e}}_d = \hat{\underline{A}} \cdot \hat{\underline{d}} \qquad (15)$$

by the system matrix $\hat{\underline{A}}$ which includes the information about the estimated K * Ka channel impulse responses. The reconstruction $\hat{\underline{e}}_d$ is performed in a signal reconstructor 5. Units 3 and 4 (FEC decoder and FEC coder) can be arranged between units 2 and 5. Unit 3 performs FEC decoding at the receiver end for the case in which FEC coding is taken into consideration in the signal processing at the transmitter end. In unit 4, a corresponding FEC coding of the estimated data takes place to obtain correct signal reconstruction. Subtracting the reconstructed received signal $\hat{\underline{e}}_d$ according to (15) from the actual received signal e according to (12) makes it possible to determine an estimate

$$\underline{\hat{n}} = \underline{e} \cdot \underline{\hat{e}}_d \qquad (16)$$

for the total interference factor n according to (7). From the estimates of the interference signals at the individual antennas, which were thus obtained, both the spatial correlation characteristics of the interference, see (11), and the temporal correlation characteristics of the interference, see (5), and thus the covariance matrix $\underline{\hat{R}}_n$ of the interference according to (6) can be estimated in an estimating unit 6.

Paragraph beginning on line 32 of page 10 has been amended as follows:

Taking into consideration the estimated covariance matrix, the signals received at the individual antennas can be subjected both to an improved channel estimate, if such a one is required, and to an improved data estimate R_n according to (13) being replaced by $\underline{\hat{R}}_n$.

Paragraph beginning on line 1 of page 11 has been amended as follows:

The procedure described up to here can be iteratively continued. Assuming that the interference scenario, and thus also the correlation characteristics of the interference, do not or do not significantly change during the provided period of estimating the matrix and in the subsequent period which is provided for estimating new data, the estimated covariance matrix $\underline{\hat{R}}_n$ can be used for estimating new data in order to achieve an improvement in the data estimate.

Please delete lines 1-22 on page 12.

On page 13, line 1, please replace “Patent Claims” with --WHAT IS CLAIMED IS--.

In the Claims:

1. (Amended) A method for the wireless data transmission using at least one transmitter and at least one receiver, the receiver having one or more receiving antennas comprising:

utilizing information on received interference signals to improve the quality of transmission of the data transmission;

obtaining quantitative information about received user signals from the received signals of one of the antennas by using a first signal processing algorithm; and

obtaining quantitative information about the received interference signals from the received signals of one of the antennas and the quantitative information obtained about the received user signals by using a second signal processing algorithm wherein the quantitative information about the received interference signals is used to generate a directional pattern at the transmitter.

2. (Amended) The method as claimed in claim 1, wherein the first signal processing algorithm provides an estimate of the transmitted user data.

3. (Amended) The method as claimed in claim 1, wherein the first signal processing algorithm provides an estimate of the characteristics of the radio channels operating between the transmitters and the receiver.

4. (Amended) The method as claimed in claim 1, wherein the second signal processing algorithm includes algorithms to reconstruct the user signals received from the receiving antennas by the quantitative information obtained about the signals.

5. (Amended) The method as claimed in claim 1, wherein the second signal processing algorithm includes a weighted or unweighted subtraction of the reconstructed received user signals from the total received signals.

Please cancel claims 6 and 7.

8. (Amended) The method as claimed in claim 1, wherein the second signal processing algorithm includes a forming of the spatial covariance matrix of the received interference signals.

9. (Amended) The method as claimed in claim 1, wherein the second signal processing algorithm includes a forming of the temporal covariance functions of the received interference signals at each of the antennas.

10. (Amended) The method as claimed in claim 1, wherein the second signal processing algorithm includes a forming of the total covariance functions of the received interference signals.

11. (Amended) The method as claimed in claim 1, wherein the second signal processing algorithm includes an estimating of the spatial, temporal and/or total covariance functions by finite temporal averaging over the received interference signals.

12. (Amended) The method as claimed in claim 1, wherein the second signal processing algorithm includes an estimating of the directions of incidence of the interference.

13. (Amended) The method as claimed in claim 1, wherein the second signal processing algorithm includes an estimating of the power and/or the spectral shape of the interference.

Please cancel claims 14 and 15.

16. (Amended) The method as claimed in claim 1, wherein the first signal processing algorithm includes a forming of the spatial covariance matrix of the received user signals.

17. (Amended) The method as claimed in claim 1, wherein the first signal processing algorithm is based on the principle of a single user detection in the case of data transmission.

18. (Amended) The method as claimed in claim 1, wherein the first signal processing algorithm is based on a principle of multi-user detection in the case of data transmission.

19. (Amended) The method as claimed in claim 1, wherein the first signal processing algorithm is based on a principle of a rake receiver in the case of data transmission.

20. (Amended) The method as claimed in claim 1, wherein the first signal processing algorithm includes forward error correction decoding at the receiver end during data transmission.

21. (Amended) The method as claimed in claim 1, wherein the first signal processing algorithm is based on a principle of the zero-forcing algorithm.

22. (Amended) The method as claimed in claim 1, wherein the first signal processing algorithm is based on a principle of maximum-likelihood estimation or minimum mean square error estimation.

Please cancel claims 23-26.

27. (New) A system for wireless data transmission, comprising:

a receiver having one or more receiving antennas utilizing information on received interference signals to improve the quality of transmission of the data transmission, wherein

quantitative information is obtained about received user signals from the received signals of one of the antennas by using a first signal processing algorithm, and

the quantitative information about the received interference signals is obtained from the received signals of one of the antennas and the quantitative information obtained about the received user signals by using a second signal processing algorithm wherein the quantitative information about the received interference signals is used for generating a directional pattern at the transmitter; and

a transmitter to generate a directional pattern based on the quantitative information about the received interference signals.

Please delete lines 1-9 on page 17.

In the Abstract:

Please replace the Abstract in its entirety with the Abstract attached hereto.

REMARKS

The above amendments to the specification, claims and abstract have been made to place the application in proper U.S. format and to conform with proper grammatical and idiomatic English. None of the amendments herein are made for reasons related to patentability. No new matter has been added.

Attached hereto is a marked-up version of the changes made to the specification and claims by the current amendment. The attached page is captioned "**Version with markings to show changes made**".

In the unlikely event that the transmittal letter is separated from this document and the Patent Office determines that an extension and/or other relief is required, applicant petitions for any required relief including extensions of time and authorizes the Commissioner to charge the cost of such petitions and/or other fees due in connection with the filing of this document to **Deposit Account No. 03-1952** referencing docket no. 449122009400. However, the Commissioner is not authorized to charge the cost of the issue fee to the Deposit Account.

Respectfully submitted,

Dated: August 27, 2001

By: Kevin R. Spivak

Kevin R. Spivak
Registration No. 43,148

Morrison & Foerster LLP
2000 Pennsylvania Avenue, N.W.
Washington, D.C. 20006-1888
Telephone: (202) 887-6924
Facsimile: (202) 263-8396

VERSION WITH MARKINGS TO SHOW CHANGES MADE

For the convenience of the Examiner, the changes made are shown below with deleted text in strikethrough and added text in underline.

In the Specification:

Page 1 before the first paragraph, has been amended to include the following insert:

CLAIM FOR PRIORITY

This application claims priority to International Application No. PCT/DE00/00005 which was published in the German language on January 3, 2000.

Page 1 before the first paragraph, please delete the following:

~~Description~~

Page 1, between lines 4 and 5 has been amended to include the following heading:

TECHNICAL FIELD OF THE INVENTION

Paragraph beginning on line 6 of page 1 has been amended as follows:

The invention relates to a method and a device for wireless data transmission, and in particular, to wireless data transmission ~~comprising one or more transmitters and at least one receiver,~~ where information about interference in a message transmission system is obtained in the receiver.

Page 1, between lines 10 and 11 has been amended to include the following heading:

BACKGROUND OF THE INVENTION

Paragraph beginning on line 11 of page 1 has been amended as follows:

In message or data transmission, it is desirable to obtain as uncorrupted a transmission of the user signals as possible, to suppress interference~~,~~ which exists at the same time and in the same frequency band in addition to the wanted signal, and thermal noise~~, respectively,~~ as well as possible in the receivers. To be able to selectively take measures against interference, it is required to know as much as possible about the characteristics of the interference. Apart from the intensity of the interference, such characteristics are, for example, ~~also~~ its spectrum, its correlation properties and the directions of incidence of the interfering signals at the receiver.

Paragraph beginning on line 24 of page 1 has been amended as follows:

In many cases such as, for example, in permanently installed radio transmission links, potential interfering influences by other permanently installed transmitters, which do not emit any user signals from the point of view of the transmission link under consideration, are known~~ a priori~~. According to the prior art, such interfering influences can be suppressed by simple measures such as directional transmission and reception,~~;~~ a procedure normally used in microwave radio. In many cases, especially in the multi-subscriber systems of mobile communication, such information on the properties of the interference is not known~~ a priori~~. Accordingly, countermeasures adapted to the interference cannot be easily taken. Assuming interference-limited multi-subscriber systems in which, therefore, the interference is essentially caused by other users of one's own system, the time correlation of the interfering signals is equal to the time correlation of the wanted signals and is thus known as long as interfering signals which are incident from different directions are uncorrelated. Knowledge of the time correlation of the interfering signals can be utilized in the receiver for improving the transmission quality by decorrelating the interference.

Paragraph beginning on line 9 of page 2 has been amended as follows:

TD-CDMA as disclosed in A. Klein, P.W. Baier: Linear unibiased data estimation in mobile radio systems applying CDMA. IEEE Journal on Selected Areas in Communications, Vol. 11, 1993, p. 1058 to 1066, as an example for third-generation mobile radio systems, uses the hybrid FDMA/TDMA/CDMA (frequency/time/code division multiple access) method. The time correlation of the interfering signals can be taken into consideration in the data detection. An example in which no information about the correlation properties of the interference are utilized is the WCDMA (wideband CDMA) disclosed in F. Adachi, K. Ohno, A. Higashi, T. Dohi, Y. Okumura: Coherent multicode DS-CDMA mobile radio access DS-CDMA mobile radio system, IEICE Transactions on Communications, Vol. E79-B, No. 9, 1996, p. 1316 to 1324 and F. Adachi, M. Sawahashi: Wideband multi-rate DS-CDMA for next generation mobile communications systems. Proc. IEEE Wireless Communications Conference (WCC'97), Boulder, 1997, p. 57 to 62, air interface concept which is also proposed for third-generation mobile radio systems and which is based on the hybrid FDMA/CDMA multiple access method.

Paragraph beginning on line 20 of page 2 has been amended as follows:

The disadvantageous factor in the transmission methods corresponding to the prior art, is that they do not obtain information on the received interference~~,~~ (or only to a very limited extent).~~, and thus~~ Hence, they do not use such information to a desirable degree for improving the transmission quality. For example, no directional information at all is obtained with respect to the interference. If multiple-antenna receivers are used, directional patterns could be generated.~~, for~~ For example, when using array antennas, which selectively have less gain for those directions from which strong interfering signals arrive at the receiver, ~~so that~~ the ratio between useful power and interference power at the receiver end is maximized. However, this would require knowledge of the directions of interference which cannot be obtained in the systems according to the prior art.

Paragraph beginning on line 1 of page 3 has been amended as follows:

The ~~considerations~~ system described above of the time correlations of the interference, ~~assumed to be known a priori~~, for example in the case of TD-CDMA, ~~too,~~ are not about obtaining information about the interference. Rather, using ~~Using a priori~~ knowledge about the interference is questionable, especially in mobile communication, since the instantaneous characteristics of the interference can greatly deviate from those assumed ~~a priori~~ due to the permanent changing in time of the spatial constellation of the mobile stations which, as a rule, is not predictable.

Paragraph beginning on line 12 of page 3 has been amended as follows:

The prerequisite of uncorrelated interference signals arriving at the receiver from different directions, which has been addressed above, is also not generally met. If the signal of an interference source propagates toward the receiver along a number of paths with different delay, and/or if the interfering signals coming from one interference source have different directions of incidence at the location of the receiver, the aggregate interference signal produced by superposition of the interference signals at the receiving location have different time correlations than the individual interference signals. ~~and thus~~ Thus, they also have different time correlations from ~~than~~ those of the user signal which have been assumed ~~a priori~~.

Page 3, between lines 25 and 26 has been amended to include the following heading:

SUMMARY OF THE INVENTION

In one embodiment of the invention, there is a method for the wireless data transmission using at least one transmitter and at least one receiver, the receiver having one or more receiving antenna. The method includes, for example, utilizing information on received interference signals to improve the quality of transmission of the data transmission, obtaining quantitative information about received user signals from the received signals of one of the antennas by using a first signal processing algorithm, and obtaining quantitative information about the received

interference signals from the received signals of one of the antennas and the quantitative information obtained about the received user signals by using a second signal processing algorithm wherein the quantitative information about the received interference signals is used to generate a directional pattern at the transmitter.

In one aspect of the invention, the first signal processing algorithm provides an estimate of the transmitted user data.

In another aspect of the invention, the first signal processing algorithm provides an estimate of the characteristics of the radio channels operating between the transmitters and the receiver.

In still another aspect of the invention, the second signal processing algorithm includes algorithms to reconstruct the user signals received from the receiving antennas by the quantitative information obtained about the signals.

In yet another aspect of the invention, the second signal processing algorithm includes a weighted or unweighted subtraction of the reconstructed received user signals from the total received signals.

In another aspect of the invention, the second signal processing algorithm includes a forming of the spatial covariance matrix of the received interference signals.

In yet another aspect of the invention, the second signal processing algorithm includes a forming of the temporal covariance functions of the received interference signals at each of the antennas.

In still another aspect of the invention, the second signal processing algorithm includes a forming of the total covariance functions of the received interference signals.

In another aspect of the invention, the second signal processing algorithm includes an estimating of the spatial, temporal and/or total covariance functions by finite temporal averaging over the received interference signals.

In still another aspect of the invention, the second signal processing algorithm includes an estimating of the directions of incidence of the interference.

In yet another aspect of the invention, the second signal processing algorithm includes an estimating of the power and/or the spectral shape of the interference.

In another aspect of the invention, the first signal processing algorithm includes a forming of the spatial covariance matrix of the received user signals.

In yet another aspect of the invention, the first signal processing algorithm is based on the principle of a single user detection in the case of data transmission.

In another aspect of the invention, the first signal processing algorithm is based on a principle of multi-user detection in the case of data transmission.

In still another aspect of the invention, the first signal processing algorithm is based on a principle of a rake receiver in the case of data transmission.

In yet another aspect of the invention, the first signal processing algorithm includes forward error correction decoding at the receiver end during data transmission.

In still another aspect of the invention, the first signal processing algorithm is based on a principle of the zero-forcing algorithm.

In yet another aspect of the invention, the first signal processing algorithm is based on a principle of maximum-likelihood estimation or minimum mean square error estimation.

In one embodiment of the invention, there is a system for wireless data transmission. The system includes, for example, a receiver having one or more receiving antennas utilizing information on received interference signals to improve the quality of transmission of the data transmission, wherein quantitative information is obtained about received user signals from the received signals of one of the antennas by using a first signal processing algorithm, and the quantitative information about the received interference signals is obtained from the received signals of one of the antennas and the quantitative information obtained about the received user signals by using a second signal processing algorithm wherein the quantitative information about the received interference signals is used for generating a directional pattern at the transmitter; and a transmitter to generate a directional pattern based on the quantitative information about the received interference signals.

Page 3, between line 25 and line 26 has been amended to include the following:

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 illustrates an exemplary receiving system in the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Paragraph beginning on line 26 or page 3 has been amended as follows:

~~The problem of procuring information on the characteristics is solved by the method according to the invention in the manner shown in claim 1,~~ In one method of the invention, ~~where~~ Ka receiving antennas are assumed. In this method, information on the user signal is first obtained from the received signals of the antennas ~~in a first step~~. From the total received signals which contain both the user signal(s) and the interference signal(s), and the information, previously obtained ~~in the first step,~~ about the user signal(s), information about the interference signal(s) can then be obtained ~~in a second step~~.

Paragraph beginning on line 1 of page 4 has been amended as follows:

~~According to the embodiment of the method according to the invention as claimed in subclaims 2, 4 and 5,~~ In one aspect of the invention, the information about the interference signals is obtained, for example, by an approximate reconstruction of the received user signals and by subsequent subtraction of the reconstructed user signals from the total of the received signals. This embodiment thus provides an estimate of the time functions $\underline{\hat{n}}^{(ka)}(t), ka = 1..Ka$ of the interference at the Ka receiving antennas.

Paragraph beginning on line 8 of page 4 has been amended as follows:

~~Further advantageous embodiments of the method according to the invention are described in subclaims 8, 9 and 10. Using~~ In another aspect of the invention, the estimates $\underline{\hat{n}}^{(ka)}(t)$ determined as above, the estimates

$$\underline{\hat{R}}_n^{(l.m)}(\tau)=E\left\{\underline{\hat{n}}^{(l)}(t)\cdot(t+\tau)\right\} \qquad l,m=1..Ka \tag{1}$$

of the temporal covariance functions of the interference signals effective at the antennas can be obtained. In addition, the normalized spatial covariance matrix

$$\underline{\hat{R}}_s=\frac{1}{\sigma^2}\begin{pmatrix} E\left\{\underline{\hat{n}}^{(1)}(t)\cdot\underline{\hat{n}}^{(1)}*(t)\right\} & E\left\{\underline{\hat{n}}^{(1)}(t)\cdot\underline{\hat{n}}^{(Ka)}*(t)\right\} \\ E\left\{\underline{\hat{n}}^{(2)}(t)\cdot\underline{\hat{n}}^{(1)}*(t)\right\} & E\left\{\underline{\hat{n}}^{(2)}(t)\cdot\underline{\hat{n}}^{(Ka)}*(t)\right\} \\ & \\ E\left\{\underline{\hat{n}}^{(Ka)}(t)\cdot\underline{\hat{n}}^{(1)}*(t)\right\} & E\left\{\underline{\hat{n}}^{(Ka)}(t)\cdot\underline{\hat{n}}^{(Ka)}*(t)\right\} \end{pmatrix} \tag{2}$$

of dimension Ka x Ka can be determined for the Ka receiving antennas, taking into consideration the interference power σ^2, which can also be determined from the estimated interference signals. In the case of both the data transmission and digital signal processing at the receiving end, discrete-time samples are available as signals which can be subdivided into finite blocks due to their burst structure. If the subscriber signals are detected burst by burst, it is sufficient to determine information about the interference burst by burst. Accordingly, the interference signals at the individual antennas,

estimated in accordance with the embodiments of the method according to one aspect of the invetion, ~~the invention according to subclaims 2, 4 and 5,~~ can be represented as vectors

$$\underline{\hat{n}}^{(ka)}=\left(\underline{\hat{n}}_1,\underline{\hat{n}}_2 \ldots \underline{\hat{n}}_{WB}\right)^T, ka=1..Ka \tag{3}$$

where $\hat{\underline{n}}_i$, i=1..WB, are the WB samples of the interference signal over one burst, since these interference signals are time-discrete and limited in time. The embodiment of the method according to ~~the invention according to subclaims 8, 9 and 10~~ one aspect thus leads to finite, discrete-time covariance functions.

Paragraph beginning on line 9 of page 5 has been amended as follows:

Instead of forming the expected value when determining the covariance functions, which requires infinite averaging over the estimated samples of the interference, the temporal averaging ~~must be~~ is preferably finite in real systems. It is performed over a previously defined number Z of bursts. In the case of a mobile radio system, Z depends on the rate of change of the constellation of mobile stations. If the constellation of mobile stations changes greatly from burst to burst, Z must be selected to be equal to one. If not, Z can be greater than 1. If the Z vectors according to (3) at the Ka antennas according to

$$\hat{\underline{N}}_t^{(ka)} = \left(\hat{\underline{n}}_1^{Ka}, \hat{\underline{n}}_2^{Ka} \ldots \hat{\underline{n}}_Z^{Ka}\right)^T, ka = 1..Ka \qquad (4)$$

are ordered into in each case WB x Z matrices, estimates

$$\hat{\underline{R}}_n^{(l.m)} = \frac{1}{Z} \cdot \hat{\underline{N}}_t^{(l)} \cdot \hat{\underline{N}}_t^{(m)*T}, \qquad l, m = 1..Ka \qquad (5)$$

of the temporal covariance matrices can be formed in derivation of (1). The following then holds for the estimate of the total covariance matrices:

Paragraph beginning on line 34 of page 6 has been amended as follows:

An important advantage, which can be achieved with the method according to the invention, lies in

that, instead of possibly faulty ~~a priori~~ information about the interference to be expected, the information about the interference is obtained from the actual received signal and is thus continuously updated. A further advantage lies in the possibility of obtaining information both on the spatial correlation characteristics of the interference and on the temporal correlation characteristics of the interference.

Paragraph beginning on line 5 of page 7 has been amended as follows:

This information can be used either directly to suppress interference when estimating the user signals from the received signals.~~, or~~ Alternatively, information about the directions of incidence of the interference at the receiver can be obtained from the information about the spatial correlation characteristics of the interference, depending on the signal processing algorithm. In the case of multi-antenna receivers, the information about the directions of incidence of the interference at the receiver or, respectively, about the spatial correlation characteristics of the interference can be used for generating directional patterns. The patterns, of which selectively have less gain in those directions from which strong interference signals arrive at the receiver, cause ~~so that~~ the ratio between useful power and interference power at the receiver end to be ~~is~~ maximized.

Paragraph beginning on line 5 of page 7 has been amended as follows:

The previous considerations relate to the receiver end. In duplex systems, each receiver is paired with a transmitter. If multi-antenna systems are used for receiving and transmitting, the information about the received interference~~,~~ (obtained in accordance with the method explained above)~~,~~ can be used for advantageously driving the antennas in the transmitting case. The basic idea of this is that sending one's own signals into the directions from which strong interference signals are incident tends to produce strong interference in other receivers. When a number of antennas is used, therefore, the knowledge of the main directions of interference at the receiver end can be generally used, independently of the transmission system considered, to radiate as

little power of the transmitted signal as possible in the directions of the main interference source and thus to reduce interference seen throughout the system.

Paragraph beginning on line 11 of page 8 has been amended as follows:

The transmitted bursts ~~consist of~~ include two data blocks and a midamble arranged between them which provides for the channel estimate at the receiver end. In the text which follows, ~~only~~ the first data block of a burst will be considered in the description of the data detection. A corresponding observation would apply to the second data block. According to R. Schmalenberger, J.J. Blanz: Multi antenna C/I balancing in the downlink of digital cellular mobile radio systems. Proc. IEEE Vehicular Technology Conference (VTC'97), Phoenix, 1997, p. 607 to 611, a system matrix $\underline{A}$ can be set up which includes both the K * Ka channel impulse responses of the K subscribers to the Ka receiving antennas and the type of signal generation at the transmitter end. Together with the total data vector $\underline{d}$, which ~~contains~~ includes the data blocks of the K subscribers, and a total interference vector $\underline{n}$, the total received-signal vector $\underline{e}$

$$\underline{e} = \underline{A}\underline{d} + \underline{n} \qquad (12)$$

is obtained. $\underline{e}$ ~~contains all~~ includes samples of the received signals at all Ka antennas which are based on the first data block of a transmitted burst. Firstly, a channel estimator 1 forms a channel estimate ~~in a first step~~ and a common detector 2 performs joint detection of the subscriber signals R. Schmalenberger, J.J. Blanz: Multi antenna C/I balancing in the downlink of digital cellular mobile radio systems. Proc. IEEE Vehicular Technology Conference (VTC'97), Phoenix, 1997, p. 607 to 611, by ~~means of~~ the generally disturbed received signals $\underline{e}$. In TD-CDMA systems, algorithms which can include the knowledge of the entire covariance matrix according to (8) are used for the joint data estimate of ~~all~~ subscribers.

Paragraph beginning on line 1 of page 9 has been amended as follows:

One example of such algorithms is the zero-forcing algorithm. In one- or multi-antenna receivers in systems according to the prior art, it is assumed that the temporal covariance matrix $\underline{R}_t$ can be determined directly from the spectral shape of the transmitted signals. In the text which follows, this covariance matrix is designated by $\underline{R}_t$. This matrix $\underline{R}_t$ is taken into consideration in the data detection, even though the actual temporal correlations of the interference signals at the receiving site may deviate from the assumed temporal correlations due to multi-path propagation of the interference from an interference source.

Paragraph beginning on line 14 of page 9 has been amended as follows:

In the case of multi-antenna receivers in systems according to the prior art, the spatial correlations of the interference are not taken into consideration in the detection of the data and/or in the channel estimate, i.e. the covariance matrix $\underline{R}_s$ is replaced by the Ka x Ka unity matrix $I^{(Ka)}$. Thus, there is no optimum data detection in the sense of the zero-forcing algorithm in systems according to the prior art. The method according to the invention can be used for improving the data estimate and the channel estimate by prior estimating of the covariance matrix $\underline{R}_n$ of the interference due to the estimating of the received interference at each antenna, as shown in ~~see~~ figure 1.

Paragraph beginning on line 14 of page 9 has been amended as follows:

To estimate the interference, a conventional data detection is first performed for a ~~more or less large~~ number of received bursts, using the matrix

$$\underline{R}_n = I^{(Ka)} \otimes \underline{\tilde{R}}_t \qquad (13)$$

for the covariance matrix $\underline{R}_n$ according to (8), using the matrix $\underline{\tilde{R}}_t$. This provides an estimate

$$\underline{\hat{d}} = \left(\underline{\hat{A}}^{*T} \underline{R}_n^{-1} \underline{\hat{A}} \right)^{-1} \underline{\hat{A}}^{*T} \underline{R}_n^{-1} \underline{e} \tag{14}$$

of the transmitted data which can be used for the approximate reconstruction of the received signal based on the user signals

$$\underline{\hat{e}}_d = \underline{\hat{A}} \cdot \underline{\hat{d}} \tag{15}$$

by ~~means of~~ the system matrix $\underline{\hat{A}}$ which includes the information about the estimated K * Ka channel impulse responses. The reconstruction $\underline{\hat{e}}_d$ is performed in a signal reconstructor 5. Units 3 and 4 (FEC decoder and FEC coder) can be arranged between units 2 and 5. Unit 3 performs FEC decoding at the receiver end for the case in which FEC coding is taken into consideration in the signal processing at the transmitter end. In unit 4, a corresponding FEC coding of the estimated data ~~must then taken~~ <u>takes</u> place to obtain correct signal reconstruction. Subtracting the reconstructed received signal $\underline{\hat{e}}_d$ according to (15) from the actual received signal $\underline{e}$ according to (12) makes it possible to determine an estimate

$$\underline{\hat{n}} = \underline{e} \cdot \underline{\hat{e}}_d \tag{16}$$

for the total interference factor $\underline{n}$ according to (7). From the estimates of the interference signals at the individual antennas, which were thus obtained, both the spatial correlation characteristics of the interference, see (11), and the temporal correlation characteristics of the interference, see (5), and thus the covariance matrix $\underline{\hat{R}}_n$ of the interference according to (6) can be estimated in an estimating unit 6.

Paragraph beginning on line 32 of page 10 has been amended as follows:

Taking into consideration the estimated covariance matrix, the signals received at the individual antennas can be subjected both to an improved channel estimate, if such a one is

required, and to an improved data estimate~~, in a second step,~~ $\underline{R}_n$ according to (13) being replaced by $\hat{\underline{R}}_n$.

Paragraph beginning on line 1 of page 11 has been amended as follows:

The procedure described up to here can be iteratively continued. Assuming that the interference scenario, and thus also the correlation characteristics of the interference, do not or do not significantly change during the provided period of estimating the matrix and in the subsequent period which is provided for estimating new data, the estimated covariance matrix $\hat{\underline{R}}_n$ can be used for estimating new data in order to achieve an improvement in the data estimate ~~already in the first step~~.

Paragraph beginning on line 1 of page 12 has been amended as follows:

~~References~~

~~[1] A. Klein, P.W. Baier: Linear unibiased data estimation in mobile radio systems applying CDMA. IEEE Journal on Selected Areas in Communications, Vol. 11, 1993, p. 1058 to 1066~~

~~[2] F. Adachi, K. Ohno, A. Higashi, T. Dohi, Y. Okumura: Coherent multicode DS-CDMA mobile radio access DS-CDMA mobile radio system, IEICE Transactions on Communications, Vol. E79-B, No. 9, 1996, p. 1316 to 1324~~

~~[3] F. Adachi, M. Sawahashi: Wideband multi-rate DS-CDMA for next generation mobile communications systems. Proc. IEEE Wireless Communications Conference (WCC'97), Boulder, 1997, p. 57 to 62~~

~~[4] R. Schmalenberger, J.J. Blanz: Multi antenna C/I balancing in the downlink of digital cellular mobile radio systems. Proc. IEEE Vehicular Technology Conference (VTC'97), Phoenix, 1997, p. 607 to 611~~

On page 13, line 1, please replace "Patent Claims" with --WHAT IS CLAIMED IS--.

In the Claims:

1. (Amended) A method for the wireless data transmission using at least one ~~or more~~ transmitter~~s~~ and at least one receiver, the receiver having one or more receiving antennas comprising: ~~in which~~

~~the receiver uses one or more receiving antennas,~~

utilizing information on received interference signals ~~is utilized for improving~~ to improve the quality of transmission of the data transmission~~,~~;

~~in a first step,~~ obtaining quantitative information about received user signals ~~is obtained~~ from the received signals of one of the ~~individual~~ antennas by using a first signal processing algorithm~~s~~~~,~~; and

~~and in a second step,~~ obtaining quantitative information about the received interference signals ~~is obtained~~ from the received signals of one of the antennas ~~or the individual antennas~~ and the quantitative information obtained about the received user signals by using a second signal processing algorithm~~s~~ wherein the quantitative information about the received interference signals is used to generate a directional pattern at the transmitter.

2. (Amended) The method as claimed in claim 1, ~~characterized in that~~ wherein the first signal processing algorithm~~s~~ provides ~~for~~ an estimate of the transmitted user data.

3. (Amended) The method as claimed in claim 1, ~~characterized in that~~ wherein the first signal processing algorithm~~s~~ provides ~~for~~ an estimate of the characteristics of the radio channels operating between the transmitters and the receiver.

4. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the second signal processing algorithm~~s~~ includes ~~contain~~ algorithms ~~for~~ to reconstruct~~ing~~ the user signals received from ~~the receiving antenna/~~the receiving antennas by ~~means of~~ the quantitative information obtained about the~~se~~ signals.

5. (Amended) The method as claimed in claim 1, wherein ~~or 3, characterized in that~~ the second signal processing algorithm~~s~~ includes ~~contain~~ a weighted or unweighted subtraction of the reconstructed received user signals from the total received signals.

Please cancel claims 6 and 7.

8. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the second signal processing algorithm~~s~~ includes ~~contain the~~ a forming of the spatial covariance matrix of the received interference signals.

9. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the second signal processing algorithm~~s~~ includes ~~contain the~~ a forming of the temporal covariance functions of the received interference signals at each of the ~~individual~~ antennas.

10. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the second signal processing algorithm~~s~~ includes ~~contain the~~ a forming of the total covariance functions of the received interference signals.

11. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the second signal processing algorithm~~s~~ includes ~~contain~~ ~~the~~ an estimating of the spatial, temporal and/or total covariance functions by finite temporal averaging over the received interference signals.

12. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the second signal processing algorithm~~s~~ includes ~~contain~~ ~~the~~ an estimating of the directions of incidence of the interference.

13. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the second signal processing algorithm~~s~~ includes ~~contain~~ ~~the~~ an estimating of the power and/or the spectral shape of the interference.

Please cancel claims 14 and 15.

16. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the first signal processing algorithm~~s~~ includes ~~contain~~ a ~~the~~ forming of the spatial covariance matrix of the received user signals.

17. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the first signal processing algorithm~~s are~~ is based on the principle of a single user detection in the case of data transmission.

18. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the first signal processing algorithm~~s are~~ is based on a ~~the~~ principle of multi-user detection in the case of data transmission.

19. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the first signal processing algorithms ~~are~~ is based on ~~the~~ a principle of ~~the~~ a rake receiver in the case of data transmission.

20. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the first signal processing algorithms includes ~~FEC (forward error correction)~~ forward error correction decoding at the receiver end ~~in the case of~~ during data transmission.

21. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the first signal processing algorithms is ~~are~~ based on a ~~the~~ principle of the zero-forcing algorithm.

22. (Amended) The method as claimed in claim 1, wherein ~~one of the preceding claims, characterized in that~~ the first signal processing algorithms ~~are~~ is based on ~~the~~ a principle of maximum-likelihood estimation or ~~MMSE (~~minimum mean square error~~)~~ estimation.

Please cancel claims 23-26.

27. (New) A system for wireless data transmission, comprising:

a receiver having one or more receiving antennas utilizing information on received interference signals to improve the quality of transmission of the data transmission, wherein

quantitative information is obtained about received user signals from the received signals of one of the antennas by using a first signal processing algorithm, and

the quantitative information about the received interference signals is obtained from the received signals of one of the antennas and the quantitative information obtained about the

received user signals by using a second signal processing algorithm wherein the quantitative information about the received interference signals is used for generating a directional pattern at the transmitter; and

a transmitter to generate a directional pattern based on the quantitative information about the received interference signals.

In the Abstract:

Please replace the Abstract in its entirety with the Abstract attached hereto.

~~Key to figure~~

~~1 Channel estimator~~

~~2 Common detector for the subscriber signals~~

~~3 FEC decoder~~

~~4 FEC coder~~

~~5 Signal reconstructor~~

~~6 Estimator for $\underline{R}_n$~~

METHOD FOR OBTAINING INFORMATION ABOUT INTERFERENCE IN THE RECEIVER OF A MESSAGE TRANSMISSION SYSTEM

Abstract

A system and device for wireless data transmission where information about interference in a message transmission system is obtained in a receiver.

1/PRTS

09/889518
JC18 Rec'd PCT/PTO 18 JUL 2001

Description

Method for obtaining information about interference in the receiver of a message transmission system

The invention relates to a method and a device for wireless data transmission comprising one or more transmitters and at least one receiver, where information about interference in a message transmission system is obtained in the receiver.

In message or data transmission, it is desirable to obtain as uncorrupted a transmission of the user signals as possible, to suppress interference, which exists at the same time and in the same frequency band in addition to the wanted signal, and thermal noise, respectively, as well as possible in the receivers. To be able to selectively take measures against interference, it is required to know as much as possible about the characteristics of the interference. Apart from the intensity of the interference, such characteristics are, for example, also its spectrum, its correlation properties and the directions of incidence of the interfering signals at the receiver.

In many cases such as, for example, in permanently installed radio transmission links, potential interfering influences by other permanently installed transmitters which do not emit any user signals from the point of view of the transmission link under consideration, are known a priori. According to the prior art, such interfering influences can be suppressed by simple measures such as directional transmission and reception; a procedure normally used in microwave radio. In many cases, especially in the multi-subscriber systems of mobile communication, such information on the properties of the interference is not known a priori. Accordingly, countermeasures adapted to the interference cannot be easily taken. Assuming interference-limited multi-subscriber systems

in which, therefore, the interference is essentially caused by other users of

one's own system, the time correlation of the interfering signals is equal to the time correlation of the wanted signals and is thus known as long as interfering signals which are incident from different directions are uncorrelated. Knowledge of the time correlation of the interfering signals can be utilized in the receiver for improving the transmission quality by decorrelating the interference.

TD-CDMA [1], as an example for third-generation mobile radio systems, uses the hybrid FDMA/TDMA/CDMA (frequency/time/code division multiple access) method. The time correlation of the interfering signals can be taken into consideration in the data detection. An example in which no information about the correlation properties of the interference are utilized is the WCDMA (wideband CDMA) [2, 3] air interface concept which is also proposed for third-generation mobile radio systems and which is based on the hybrid FDMA/CDMA multiple access method.

The disadvantageous factor in the transmission methods corresponding to the prior art is that they do not obtain information on the received interference, or only to a very limited extent, and thus do not use such information to a desirable degree for improving the transmission quality. For example, no directional information at all is obtained with respect to the interference. If multiple-antenna receivers are used, directional patterns could be generated, for example when using array antennas, which selectively have less gain for those directions from which strong interfering signals arrive at the receiver so that the ratio between useful power and interference power at the receiver end is maximized. However, this would require knowledge of the directions of interference which cannot be obtained in the systems according to the prior art.

The considerations described above of the time correlations of the interference, assumed to be known a priori, for example in the case of TD-CDMA, too, are not about obtaining information about the interference. Using a priori knowledge about the interference is questionable, especially in mobile communication, since the instantaneous characteristics of the interference can greatly deviate from those assumed a priori due to the permanent changing in time of the spatial constellation of the mobile stations which, as a rule, is not predictable.

The prerequisite of uncorrelated interference signals arriving at the receiver from different directions, which has been addressed above, is also not generally met. If the signal of an interference source propagates toward the receiver along a number of paths with different delay and/or if the interfering signals coming from one interference source have different directions of incidence at the location of the receiver, the aggregate interference signal produced by superposition of the interference signals at the receiving location have different time correlations than the individual interference signals and thus also different time correlations than those of the user signal which have been assumed a priori.

The problem of procuring information on the characteristics is solved by the method according to the invention in the manner shown in claim 1, where Ka receiving antennas are assumed. In this method, information on the user signal is first obtained from the received signals of the antennas in a first step. From the total received signals which contain both the user signal(s) and the interference signal(s), and the information, obtained in the first step, about the user signal(s), information about the interference signal(s) can then be obtained in a second step.

According to the embodiment of the method according to the invention as claimed in subclaims 2, 4 and 5, the information about the

interference signals is obtained, for example, by an approximate reconstruction of the received user signals and by subsequent subtraction of the reconstructed user signals from the total of the received signals. This embodiment thus provides an estimate of the time functions $\hat{\underline{n}}^{(ka)}(t), ka=1..Ka$ of the interference at the Ka receiving antennas.

Further advantageous embodiments of the method according to the invention are described in subclaims 8, 9 and 10. Using the estimates $\hat{\underline{n}}^{(ka)}(t)$ determined as above, the estimates

$$\hat{\underline{R}}_n^{(l.m)}(\tau)=E\left\{\hat{\underline{n}}^{(l)}(t)\cdot(t+\tau)\right\} \qquad l,m=1..Ka \tag{1}$$

of the temporal covariance functions of the interference signals effective at the antennas can be obtained. In addition, the normalized spatial covariance matrix

$$\hat{\underline{R}}_s=\frac{1}{\sigma^2}\begin{pmatrix} E\left\{\hat{\underline{n}}^{(1)}(t)\cdot\hat{\underline{n}}^{(1)}*(t)\right\} & E\left\{\hat{\underline{n}}^{(1)}(t)\cdot\hat{\underline{n}}^{(Ka)}*(t)\right\} \\ E\left\{\hat{\underline{n}}^{(2)}(t)\cdot\hat{\underline{n}}^{(1)}*(t)\right\} & E\left\{\hat{\underline{n}}^{(2)}(t)\cdot\hat{\underline{n}}^{(Ka)}*(t)\right\} \\ & \\ E\left\{\hat{\underline{n}}^{(Ka)}(t)\cdot\hat{\underline{n}}^{(1)}*(t)\right\} & E\left\{\hat{\underline{n}}^{(Ka)}(t)\cdot\hat{\underline{n}}^{(Ka)}*(t)\right\} \end{pmatrix} \tag{2}$$

of dimension Ka x Ka can be determined for the Ka receiving antennas, taking into consideration the interference power σ^2, which can also be determined from the estimated interference signals. In the case of both the data transmission and digital signal processing at the receiving end, discrete-time samples are available as signals which can be subdivided into finite blocks due to their burst structure. If the subscriber signals are detected burst by burst, it is sufficient to determine information about the interference burst by burst. Accordingly, the interference signals at the individual antennas,

estimated in accordance with the embodiments of the method according to the invention according to subclaims 2, 4 and 5, can be represented as vectors

$$\underline{\hat{n}}^{(ka)} = \left(\underline{\hat{n}}_1, \underline{\hat{n}}_2 \ldots \underline{\hat{n}}_{WB}\right)^T, ka = 1..Ka \tag{3}$$

where $\underline{\hat{n}}_i$, i=1..WB, are the WB samples of the interference signal over one burst, since these interference signals are time-discrete and limited in time. The embodiment of the method according to the invention according to subclaims 8, 9 and 10 thus leads to finite, discrete-time covariance functions.

Instead of forming the expected value when determining the covariance functions, which requires infinite averaging over the estimated samples of the interference, the temporal averaging must be finite in real systems. It is performed over a previously defined number Z of bursts. In the case of a mobile radio system, Z depends on the rate of change of the constellation of mobile stations. If the constellation of mobile stations changes greatly from burst to burst, Z must be selected to be equal to one. If not, Z can be greater than 1. If the Z vectors according to (3) at the Ka antennas according to

$$\underline{\hat{N}}_t^{(ka)} = \left(\underline{\hat{n}}_1^{Ka}, \underline{\hat{n}}_2^{Ka} \ldots \underline{\hat{n}}_Z^{Ka}\right)^T, ka = 1..Ka \tag{4}$$

are ordered into in each case WB x Z matrices, estimates

$$\underline{\hat{R}}_n^{(l.m)} = \frac{1}{Z} \cdot \underline{\hat{N}}_t^{(l)} \cdot \underline{\hat{N}}_t^{(m)*T}, \qquad l, m = 1..Ka \tag{5}$$

of the temporal covariance matrices can be formed in derivation of (1). The following then holds for the estimate of the total covariance matrices:

$$\underline{\hat{R}}_n = \begin{pmatrix} \underline{\hat{R}}_n^{(1,1)} & \underline{\hat{R}}_n^{(1,2)} & .. & \underline{\hat{R}}_n^{(1,Ka)} \\ \underline{\hat{R}}_n^{(2,1)} & \underline{\hat{R}}_n^{(2,2)} & .. & \underline{\hat{R}}_n^{(2,Ka)} \\ & & & \\ \underline{\hat{R}}_n^{(Ka,1)} & \underline{\hat{R}}_n^{(Ka,2)} & .. & \underline{\hat{R}}_n^{(Ka,Ka)} \end{pmatrix} \tag{6}$$

The actual interference vectors $\underline{n}^{(ka)}(t)$, ka=1..Ka, at the Ka antennas can be correlated with the estimated interference vectors $\hat{\underline{n}}^{(ka)}(t)$, ka=1..Ka, according to (3) and combined in a total interference vector

$$\underline{n}^{(ka)} = \left(\underline{n}^{(1)T}, \underline{n}^{(2)T} .. \underline{n}^{(Ka)T}\right)^T \tag{7}$$

The actual total covariance matrix of the interference is as obtained as

$$\underline{R}_n = E\left\{\underline{n}\underline{n}^{*T}\right\} \tag{8}$$

Assuming uncorrelated interference signals arriving at the receiving site from various directions, the actual total covariance matrix $\underline{R}_n$ according to (8) can be split into a spatial covariance matrix $\underline{R}_s$ and a temporal covariance matrix $\underline{R}_n$ which is equal for all received signals at the Ka receiving antennas, so that the following holds true:

$$\underline{R}_n = \underline{R}_s \otimes \underline{R}_t \,. \tag{9}$$

If it is only intended to obtain an estimate $\hat{\underline{R}}_s$ of the spatial covariance matrix, the Ka x Z WB matrix is used as a basis

$$\hat{\underline{N}}_s = \begin{pmatrix} \hat{\underline{n}}_1^{(1)T} & \hat{\underline{n}}_2^{(1)T} & .. & \hat{\underline{n}}_Z^{(1)T} \\ .. & .. & .. & .. \\ \hat{\underline{n}}_1^{(Ka)T} & \hat{\underline{n}}_2^{(Ka)T} & .. & \hat{\underline{n}}_Z^{(Ka)T} \end{pmatrix} \tag{10}$$

and the required estimate $\hat{\underline{R}}_s$ is determined according to

$$\hat{\underline{R}}_s = \frac{1}{Z \cdot WB} \cdot \hat{\underline{N}}_s \cdot \hat{\underline{N}}_s^{*T} \tag{11}$$

that, instead of possibly faulty a priori information about the interference to be expected, the information about the interference is obtained from the actual received signal and is thus continuously updated. A

An important advantage, which can be achieved with the method according to the invention, lies in

further advantage lies in the possibility of obtaining information both on the spatial correlation characteristics of the interference and on the temporal correlation characteristics of the interference.

This information can be used either directly to suppress interference when estimating the user signals from the received signals, or information about the directions of incidence of the interference at the receiver can be obtained from the information about the spatial correlation characteristics of the interference, depending on the signal processing algorithm. In the case of multi-antenna receivers, the information about the directions of incidence of the interference at the receiver or, respectively, about the spatial correlation characteristics of the interference can be used for generating directional patterns which selectively have less gain in those directions from which strong interference signals arrive at the receiver so that the ratio between useful power and interference power at the receiver end is maximized.

The previous considerations relate to the receiver end. In duplex systems, each receiver is paired with a transmitter. If multi-antenna systems are used for receiving and transmitting, the information about the received interference, obtained in accordance with the method explained above, can be used for advantageously driving the antennas in the transmitting case. The basic idea of this is that sending one's own signals into the directions from which strong interference signals are incident tends to produce strong interference in other receivers. When a number of antennas is used, therefore, the knowledge of the main directions of interference at the receiver end can be generally used, independently of the transmission system considered, to radiate as little power of the transmitted signal as possible in the directions of the

As an exemplary embodiment, one possible implementation of the method according to the invention for obtaining information with respect to the interference is presented with reference to the discrete-time model

main interference source and thus to reduce interference seen throughout the system.

of the uplink of a TD-CDMA mobile radio system in the text which follows. Moreover, it is shown here how the information obtained can be used for improving the quality of transmission. Use in other transmission systems is also included in the scope of the invention.

The corresponding receiving system is shown in figure 1. It is assumed that K mobile subscribers are simultaneously transmitting in the same frequency band and time slot and the subscriber signals are separated by subscriber-specific CDMA codes.

The transmitted bursts consist of two data blocks and a midamble arranged between them which provides for the channel estimate at the receiver end. In the text which follows, only the first data block of a burst will be considered in the description of the data detection. A corresponding observation would apply to the second data block. According to [4], a system matrix $\underline{A}$ can be set up which includes both the K * Ka channel impulse responses of the K subscribers to the Ka receiving antennas and the type of signal generation at the transmitter end. Together with the total data vector $\underline{d}$, which contains the data blocks of the K subscribers, and a total interference vector $\underline{n}$, the total received-signal vector $\underline{e}$

$$\underline{e} = \underline{A}\underline{d} + \underline{n} \tag{12}$$

is obtained. $\underline{e}$ contains all samples of the received signals at all Ka antennas which are based on the first data block of a transmitted burst. Firstly, a channel estimator 1 forms a channel estimate in a first step and a common detector 2 performs joint detection of the subscriber signals [4] by means of the generally disturbed received signals $\underline{e}$. In TD-CDMA systems, algorithms which can include the knowledge of the entire covariance matrix according to (8) are used for the joint data estimate of all subscribers.

One example of such algorithms is the zero-forcing algorithm. In one- or multi-antenna receivers in systems according to the prior art, it is assumed that the temporal covariance matrix $\underline{R}_t$ can be determined directly from the spectral shape of the transmitted signals. In the text which follows, this covariance matrix is designated by $\underline{R}_t$. This matrix $\underline{R}_t$ is taken into consideration in the data detection even though the actual temporal correlations of the interference signals at the receiving site may deviate from the assumed temporal correlations due to multi-path propagation of the interference from an interference source.

In the case of multi-antenna receivers in systems according to the prior art, the spatial correlations of the interference are not taken into consideration in the detection of the data and/or in the channel estimate, i.e. the covariance matrix $\underline{R}_s$ is replaced by the Ka x Ka unity matrix $I^{(Ka)}$. Thus there is no optimum data detection in the sense of the zero-forcing algorithm in systems according to the prior art. The method according to the invention can be used for improving the data estimate and the channel estimate by prior estimating of the covariance matrix $\underline{R}_n$ of the interference due to the estimating of the received interference at each antenna, see figure 1.

To estimate the interference, a conventional data detection is first performed for a more or less large number of received bursts, using the matrix

$$\underline{R}_n = I^{(Ka)} \otimes \underline{\widetilde{R}}_t \tag{13}$$

for the covariance matrix $\underline{R}_n$ according to (8), using the matrix $\underline{\widetilde{R}}_t$. This provides an estimate

$$\underline{\hat{d}} = \left(\underline{\hat{A}}^{*T} \underline{R}_n^{-1} \underline{\hat{A}}\right)^{-1} \underline{\hat{A}}^{*T} \underline{R}_n^{-1} \underline{e} \tag{14}$$

of the transmitted data which can be used for the approximate reconstruction of the received signal based on the user signals

$$\underline{\hat{e}}_d = \underline{\hat{A}} \cdot \underline{\hat{d}} \qquad (15)$$

by means of the system matrix $\underline{\hat{A}}$ which includes the information about the estimated K * Ka channel impulse responses. The reconstruction $\underline{\hat{e}}_d$ is performed in a signal reconstructor 5. Units 3 and 4 (FEC decoder and FEC coder) can be arranged between units 2 and 5. Unit 3 performs FEC decoding at the receiver end for the case in which FEC coding is taken into consideration in the signal processing at the transmitter end. In unit 4, a corresponding FEC coding of the estimated data must then taken place to obtain correct signal reconstruction. Subtracting the reconstructed received signal $\underline{\hat{e}}_d$ according to (15) from the actual received signal $\underline{e}$ according to (12) makes it possible to determine an estimate

$$\underline{\hat{n}} = \underline{e} \cdot \underline{\hat{e}}_d \qquad (16)$$

for the total interference factor $\underline{n}$ according to (7). From the estimates of the interference signals at the individual antennas, which were thus obtained, both the spatial correlation characteristics of the interference, see (11), and the temporal correlation characteristics of the interference, see (5), and thus the covariance matrix $\underline{\hat{R}}_n$ of the interference according to (6) can be estimated in an estimating unit 6.

Taking into consideration the estimated covariance matrix, the signals received at the individual antennas can be subjected both to an improved channel estimate, if such a one is required, and to an improved data estimate, in a second step, $\underline{R}_n$ according to (13) being replaced by $\underline{\hat{R}}_n$.

The procedure described up to here can be iteratively continued. Assuming that the interference scenario, and thus also the correlation characteristics of the interference, do not or not significantly change during the provided period of estimating the matrix and in the subsequent period which is provided for estimating new data, the estimated covariance matrix $\underline{\hat{R}}_n$ can be used for estimating new data in order to achieve an improvement in the data estimate already in the first step.

References

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[2] F. Adachi, K. Ohno, A. Higashi, T. Dohi, Y. Okumura: Coherent multicode DS-CDMA mobile radio access DS-CDMA mobile radio system, IEICE Transactions on Communications, Vol. E79-B, No. 9, 1996, p. 1316 to 1324

[3] F. Adachi, M. Sawahashi: Wideband multi-rate DS-CDMA for next generation mobile communications systems. Proc. IEEE Wireless Communications Conference (WCC'97), Boulder, 1997, p. 57 to 62

[4] R. Schmalenberger, J.J. Blanz: Multi antenna C/I balancing in the downlink of digital cellular mobile radio systems. Proc. IEEE Vehicular Technology Conference (VTC'97), Phoenix, 1997, p. 607 to 611

Patent claims

1. A method for the wireless data transmission using one or more transmitters and at least one receiver, in which

- the receiver uses one or more receiving antennas,
- information on received interference signals is utilized for improving the quality of transmission of the data transmission,
- in a first step, quantitative information about received user signals is obtained from the received signals of the individual antennas by using first signal processing algorithms,
- and in a second step, quantitative information about the received interference signals is obtained from the received signals of the antenna or the individual antennas and the quantitative information obtained about the received user signals by using second signal processing algorithms,

characterized in that the quantitative information about the received interference signals is used for generating a directional pattern at the transmitter end.

2. The method as claimed in claim 1, characterized in that the first signal processing algorithms provide for an estimate of the transmitted user data.

3. The method as claimed in claim 1, characterized in that the first signal processing algorithms provide for an estimate of the characteristics of the radio channels operating between the transmitters and the receiver.

4. The method as claimed in one of the preceding claims, characterized in that

the second signal processing algorithms contain algorithms for reconstructing the user signals received from the receiving antenna/the receiving antennas by means of the quantitative information obtained about these signals.

5. The method as claimed in claim 1 or 3, characterized in that the second signal processing algorithms contained a weighted or unweighted subtraction of the reconstructed received user signals from the total received signals.

6. The method as claimed in one of the preceding claims, characterized in that the second signal processing algorithms contain the forming of the spatial covariance matrix of the received interference signals.

7. The method as claimed in one of the preceding claims, characterized in that the second signal processing algorithms contain the forming of the temporal covariance functions of the received interference signals at the individual antennas.

8. The method as claimed in one of the preceding claims, characterized in that the second signal processing algorithms contain the forming of the total covariance functions of the received interference signals.

9. The method as claimed in one of the preceding claims, characterized in that the second signal processing algorithms contain the estimating of the spatial, temporal and/or total covariance functions by finite temporal averaging over the received interference signals.

10. The method as claimed in one of the preceding claims,

characterized in that the second signal processing algorithms contain the estimating of the directions of incidence of the interference.

11. The method as claimed in one of the preceding claims, characterized in that the second signal processing algorithms contain the estimating of the power and/or the spectral shape of the interference.

12. The method as claimed in one of the preceding claims, characterized in that the first signal processing algorithms contain the forming of the spatial covariance matrix of the received user signals.

13. The method as claimed in one of the preceding claims, characterized in that the first signal processing algorithms are based on the principle of single user detection in the case of data transmission.

14. The method as claimed in one of the preceding claims, characterized in that the first signal processing algorithms are based on the principle of multi-user detection in the case of data transmission.

15. The method as claimed in one of the preceding claims, characterized in that the first signal processing algorithms are based on the principle of the rake receiver in the case of data transmission.

16. The method as claimed in one of the preceding claims, characterized in that the first signal processing algorithms include FEC (forward error correction) decoding at the receiver end in the case of data transmission.

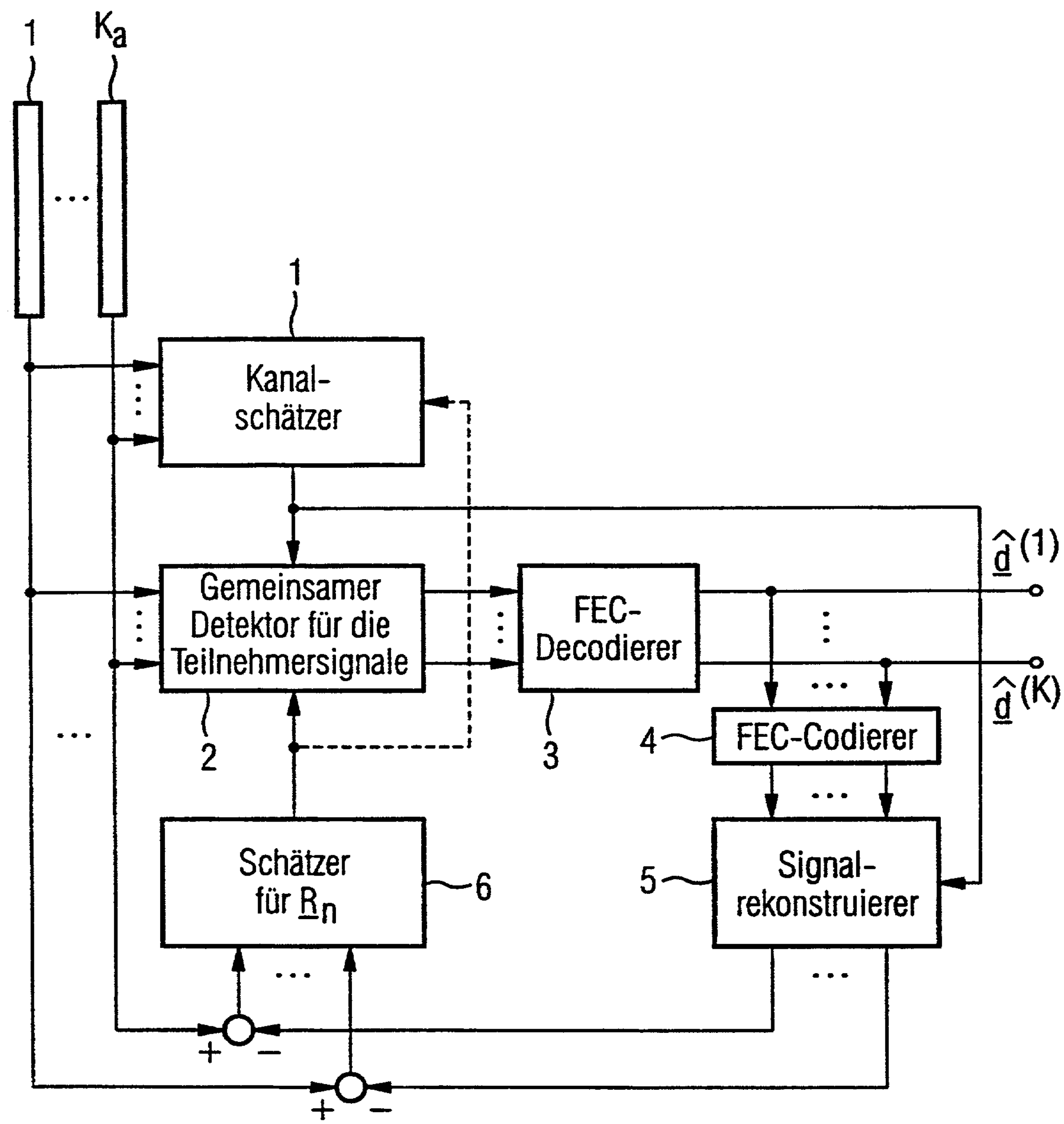
17. The method as claimed in one of the preceding claims, characterized in that the first signal processing algorithms are based on the principle of the zero-forcing algorithm.

18. The method as claimed in one of the preceding claims, characterized in that the first signal processing algorithms are based on the principle of maximum-likelihood estimation or MMSE (minimum mean square error) estimation.

19. An arrangement for carrying out the method as claimed in claim 1.

Key to figure

1 Channel estimator
2 Common detector for the subscriber signals
3 FEC decoder
4 FEC coder
5 Signal reconstructor
6 Estimator for $\underline{R}_n$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Method for obtaining information regarding interference in the receiver of a message transmission system

the specification of which

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Prior foreign appplications
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Priority Claimed

19901877.4 (Number) (Nummer)	DE (Country) (Land)	19.01.1999 (Day Month Year Filed) (Tag Monat Jahr eingereicht)	☒ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein
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PCT/DE00/00005 (Application Serial No.) (Anmeldeseriennummer)	03.01.2000 (Filing Date D, M, Y) (Anmeldedatum T, M, J)	anhängig (Status) (patentiert, anhängig, aufgegeben)	pending (Status) (patented, pending, abandoned)
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Staatsangehörigkeit: DE	Citizenship: DE
Postanschrift: BURGUNDER STR. 6	Post Office Address: BURGUNDER STR. 6
67661 KAISERSLAUTERN	67661 KAISERSLAUTERN

Voller Name des zweiten Miterfinders (falls zutreffend):	Full name of second joint inventor, if any:
Dr. MARTIN HAARDT	Dr. MARTIN HAARDT
Unterschrift des Erfinders / Datum: [signature] 20.7.01	Second Inventor's signature / Date: [signature] 7/20/01
Wohnsitz: MUENCHEN, DEUTSCHLAND	Residence: MUENCHEN, GERMANY DEX
Staatsangehörigkeit: DE	Citizenship: DE
Postanschrift: WENGLEINSTR. 3	Post Office Address: WENGLEINSTR. 3
81477 MUENCHEN	81477 MUENCHEN

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).

1400

2-w

3-00

Voller Name des dritten Miterfinders:	Full name of third joint inventor:
MARTIN WECKERLE	MARTIN WECKERLE
Unterschrift des Erfinders: Martin Weckerle — Datum: 3.8.01	Inventor's signature: Martin Weckerle — Date: 8/3/01
Wohnsitz: Neustadt ~~KAISERSLAUTERN~~, DEUTSCHLAND	Residence: Neustadt ~~KAISERSLAUTERN~~, GERMANY
Staatsangehörigkeit: DE	Citizenship: DE DEX
Postanschrift: Karlstr. 3 ~~ALBERT SCHWEITZER-STR.60~~	Post Office Address: Karlstr. 3 ~~ALBERT SCHWEITZER-STR.60~~
~~67655 KAISERSLAUTERN~~ 67433 Neustadt	~~67655 KAISERSLAUTERN~~ 67433 Neustadt

Voller Name des vierten Miterfinders:	Full name of fourth joint inventor:
Unterschrift des Erfinders — Datum	Inventor's signature — Date
Wohnsitz ,	Residence ,
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

Voller Name des fünften Miterfinders:	Full name of fifth joint inventor:
Unterschrift des Erfinders — Datum	Inventor's signature — Date
Wohnsitz ,	Residence ,
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

Voller Name des sechsten Miterfinders:	Full name of sixth joint inventor:
Unterschrift des Erfinders — Datum	Inventor's signature — Date
Wohnsitz ,	Residence ,
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).